MINING HEALTH AND SAFETY UPDATE

NIOSH

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Photo by Ronald S. Conti, NIOSH Pittsburgh Research Center

Are You Really Prepared for an Underground Mine Fire?

"Mine rescue is basically after the fact. What you really need is to do something before it gets to the point that you have to call mine rescue in. The biggest threat to our employment has got to be fire."

THE MESSAGE IMPLICIT IN THE phrase "fire preparedness" is that *prevention* is key. Over the past 10 years, our mine safety researchers interviewed hundreds of people who had first-hand experience with underground mine fires. These included first-responders (regular miners), fire brigade members, mine rescue teams,

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Comparing the Performance of Self-Contained Self-Rescuers (SCSR's)

NIOSH RECENTLY ASSESSED the performance of four second-generation oxygen self-rescuers approved for use in the United States. Mine operators and manufacturers can use the results of this study to compare these units based on their performance characteristics.

Three of the self-rescuers had a rated duration of 60 minutes: the CSE SR-100, Draeger OXY K Plus, and MSA Portal-Pack. They are marketed as direct replacements

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This issue's focus:

HUMAN FACTORS
FIRES AND EXPLOSIONS
LIFE SUPPORT
EQUIPMENT SAFETY

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Public Health Service
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CENTERS FOR DISEASE CONTROL AND PREVENTION

Are You Really Prepared for an Underground Mine Fire?

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and emergency command center personnel. We excerpted some of their experiences to create this article.

Statistics About Mine Fires

Pomroy and Carigiet in 1995 assessed industry progress in preventing underground coal mine fires. They analyzed 164 fires reported to the Mine Safety and Health Administration (MSHA) from 1978 to 1992. Figure 1 summarizes these incidents (we augmented the graph with data for 1993-95). They made several observations from their 15-year analysis:

- These 164 fires resulted in 30 fatalities and 43 injuries. A total of 10 injuries and 27 fatalities are attributed to one event: the Wilberg fire of 1984. The last fatality occurred in 1987.

- Equipment was the primary cause of these fires. However, they observed increasing trends for roof bolters, power centers, transformers, electrical equipment, conveyors, and conveyor drives. Diesel equipment was involved in two fires. Reportable fires involving rubber hose, tires, oil, and grease are declining.

- Approximately 85% of the fires were first detected by mine personnel who saw smoke, smelled smoke, or saw the fire start.

- About 45% of these incidents resulted in evacuating the entire mine. Another 15% required evacuation of inby personnel only. Evacuations are far more likely to occur today than in earlier years of the study. The researchers noted that this trend may be due to management's increased awareness and caution concerning safety risks to personnel.

- The fires occurred in seven general locations. This implies that fire initiation is a mine-wide problem.

- Most fires were electrical (such as a short circuit or insulation failure). This was followed by fires due to friction (such as a conveyor belt rubbing on a pulley or stationary object), welding, flame cutting, and spontaneous combustion.

Miners' Suggestions

Official accounts of mine fires and related injuries are the most important measure of progress in mine fire preparedness. However, many incipient fires are not reported because they are extinguished quickly and without injury. To obtain a better understanding of fire preparedness, we interviewed 214 miners from 7 underground coal mines. The purpose was to assess their state of preparedness and the technology that they use to detect and respond to underground mine fires.

Many miners suggested ways that their work force could be better prepared to respond to fires. Ideas ranged from seeing for themselves where fire-fighting equipment is stored in their mine to conducting full-scale fire drills with nontoxic smoke generators. Although the need for hands-on training was of primary concern, several workers suggested organizational and technological improvements. Many of their ideas concerned better communications, including developing a crew plan and regularly cleaning and maintaining signs. Other miners perceived shortcomings in equipment availability or a lack of adequate water pressure at their mine.

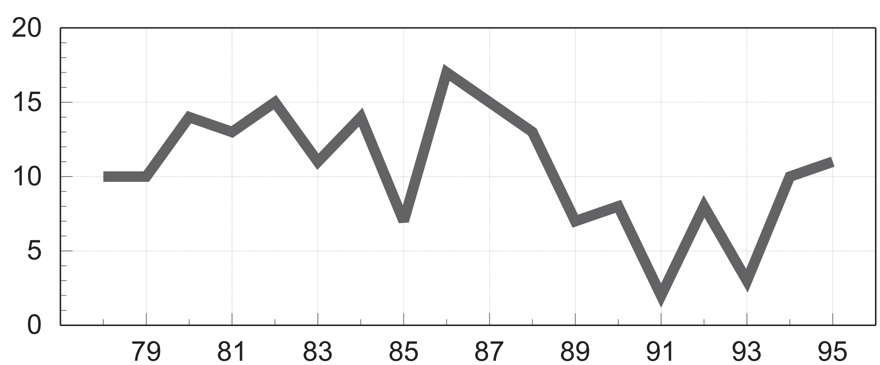

Figure 1.—U.S. underground coal mine fires (1978-95).

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UPDATE

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Based on our research, we developed several recommendations for better fire preparedness:

- Determine the selection and placement of fire detection sensors. Although general guidelines can be used, this should also be based on a site-specific analysis of fire risk.

- Establish and test warning and communication protocols in case of emergency. This might result in a better choice of markers (e.g., we are currently researching the effectiveness of strobe lights) and better locations for those markers (e.g., near the bottom where smoke is less dense).

- Develop and test a water delivery system that can deliver hundreds of gallons of water per minute for sustained periods.

- Conduct formal fire preparedness audits.

- Develop case studies of fire incidents that can be used as teaching and assessment tools.

- Provide opportunities for hands-on training that can be incorporated into fire drills.

We are continuing to research each of these areas primarily through studies at our Lake Lynn Laboratory near Fairchance, PA, and cooperative agreements with mining firms. Several resources and facilities are available to help the mining industry enhance its ability to prevent, detect, and respond to underground mine fires. These include MSHA's National Mine Health and Safety Academy, Beckley, WV, NIOSH Open Industry Briefings at Lake Lynn Laboratory, and the West Virginia Mining Extension Service.

Studying *how* miners use critical prevention, detection, and response systems offers important insight into the state of fire preparedness at any operation. Mines can use this approach to assess their own preparedness.

For more information about the research discussed here, please request publication Nos. 3, 11, and 15 from the publications listing on page 7 of this Update.

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Comparing the Performance of SCSR's

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for their predecessors (the AU-9A1, OXY-SR 60B, and 60-minute SCSR, respectively). We also tested the 10-minute-rated Ocenco M-20. This unit is intended to be used in conjunction with the 60-minute-rated Ocenco EBA 6.5. It is designed to be worn on the belt, replacing a similarly sized filter self-rescuer. Although the other self-rescuers are also intended to be belt-worn, there has been some resistance to this among users, even though the apparatus are much smaller than their predecessors.

Table 1 lists the models we included in this study, along with the oxygen source, rated duration, weight, and approximate volume. The Ocenco M-20 was the lightest and smallest unit; the CSE SR-100 was the lightest and smallest of the 60-minute apparatus.

We tested the self-rescuers on a breathing and metabolic simulator, continuously monitoring inhaled levels of carbon dioxide and oxygen, inhaled wet- and dry-bulb temperatures, and breathing pressures. The metabolic demand placed on the apparatus was a moderately high workload for a miner of average weight.

Table 2 presents some results of this study. We tested five new units

Table 1.—Self-rescuers included in the study

Apparatus tested	Oxygen source	Rated duration, min	Weight, kg		Volume in case, L
			In case	In use	
CSE SR-100	Chemical	60	2.791	2.186	3.6
Draeger OXY K Plus	Chemical	60	2.887	2.450	5.0
MSA Portal-Pack	Chemical	60	3.047	2.075	4.5
Ocenco M-20	Compressed	10	1.465	0.9	2.2

Table 2.—Mean values for five test parameters (standard deviations in parentheses)

Apparatus tested	Actual duration, min	Usable O_2, L	Inhaled CO_2, %	Temperature, °C	
				Wet-bulb	Dry-bulb
CSE SR-100	65 (1)	88 (1)	2.0 (0.1)	32 (0)	48 (1)
Draeger OXY K Plus	72 (6)	97 (8)	1.4 (0.2)	31 (2)	48 (2)
MSA Portal-Pack	71 (3)	96 (4)	3.3 (0.4)	29 (1)	45 (3)
Ocenco M-20	18 (1)	24 (1)	2.3 (0.2)	46 (0)	55 (1)

for each manufacturer. Mean and standard deviations are reported for the following test parameters: actual duration of the unit (in minutes), usable oxygen produced (in liters), percent of inhaled carbon dioxide, and wet- and dry-bulb temperatures (in degrees Celsius).

In summary, the Draeger OXY K Plus and the MSA Portal-Pack had the highest quantities of usable oxygen. The Draeger had the highest oxygen levels (not shown) and the lowest inhaled carbon dioxide levels. It also had the lowest breathing resistances (not shown). The MSA generated the lowest temperatures.

For a more detailed report of the findings of this study, please request publication No. 8 from the publications listing on page 7 of this Update.

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From the Editor...

With the abolition of the U.S. Bureau of Mines (USBM), health and safety research at the research centers at Pittsburgh, PA, and Spokane, WA, was permanently assigned to the National Institute for Occupational Safety and Health (NIOSH) in October 1996. NIOSH is part of the Centers for Disease Control and Prevention within the U.S. Department of Health and Human Services. The transition of mining health and safety research from the former USBM into NIOSH creates a novel approach and partnership for improving the health and reducing the risks of injury and fatality for all U.S. mine workers.

To receive additional information about mining issues or other occupational safety and health problems, call 1-800-35-NIOSH (1-800-356-4674), or visit the NIOSH Home Page on the World Wide Web at http://www.cdc.gov/niosh/homepage.html. *Mining Health and Safety Update* is now available on our web site.

We encourage you to contact the researchers listed at the end of each article if you have any questions or comments. Note that their e-mail addresses have changed since our last *Update.*

Additions, changes, or deletions to our mailing list should be directed to Rose Ann Crotsley, (412) 892-6609 (rkc6@cdc.gov).

Barricading Makes a Comeback?

UNDERGROUND COAL MINERS have always faced the risk of having to escape a mine fire or explosion. Before self-rescue devices, they would often barricade rather than risk escaping bare-faced through a toxic atmosphere. Barricades were often crudely constructed of brattice curtain, timbers, nails, and whatever other materials the miners could find. However, barricaded miners were often found dead because their chamber became oxygen-deficient, carbon monoxide leaked in, or they tore down the barricade too soon upon hearing a rescue team approach. Even after filter self-rescuer devices were introduced, miners were taught barricading techniques. Following advances in sophisticated seismic sensing equipment in the 1970's, a signaling protocol was developed for locating barricaded miners.

The barricading ideology began to change in the early 1980's with the introduction of self-contained self-rescuers (SCSR's) that provided miners with enough oxygen to reach the first split of fresh air. Although MSHA still mandates instruction in barricading, greater emphasis is now placed on teaching miners to use SCSR's proficiently and to be knowledgeable about their escape routes. Only recently has at least one mine operator begun to revisit barricading as an alternative to escape.

Since early 1996, this U.S. coal mine has been mining super longwall panels up to 1,000 feet wide and nearly 19,000 feet long. What is unique about this mine is the pitch of the coal seam. Starting with the setup entries at the back end of the panels and proceeding outby for about 9,000 feet, the coalbed dips downward on a 7% to 10% pitch. Once mining has reached midpanel, the coal begins pitching upward on about the same percent grade (i.e., the coal forms a basin at midpanel). As a result, miners working on the longwall must escape uphill for about 1.75 miles before reaching the mains. From there, they continue uphill on grades of up to 11% to reach the portal. Escaping this mine on foot would require significant time, energy, and oxygen.

As a result, mine personnel constructed barricade chambers in crosscuts in the mains and between the longwall panels. The chambers have large concrete bulkheads on each end that are fitted with an airlock. Boreholes from the surface provide fresh air and water. The chamber in the mains is fitted with a lined shaft that permits lowering an escape capsule from the surface. The mine stores additional SCSR's in the chambers, along with first aid and other supplies.

NIOSH researchers worked with mine personnel to develop a simulated decision-making exercise to teach workers about barricading. The goals were to (1) introduce the barricade chambers to the miners, (2) inform the work force about procedures in place for its mine rescue team to support an evacuation, and (3) provide an opportunity to explore other escape strategies for super longwall panels.

We administered the exercise to 172 individuals at the mine. After each class, we asked the miners to complete a questionnaire. According to the results, 99% said that the situation described in the training exercise could happen in real life and 96% indicated that the exercise helped them remember something important regarding escape from a mine fire. Finally, although only 57% of the trainees had seen the barricade chambers, over 86% said that they would use one in an emergency. In summary, the exercise heightened awareness of the mine's barricade chambers and showed workers that there are situations where barricading should be considered as an option.

As more mines consider super longwall panels, escape will become an important concern. Operators will need to address whether it is feasible for their miners to traverse long distances in an evacuation. If not, other options may need to be considered.

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Training

"Highlighted" Versus "Degraded" Technique

WHAT DO FIGHTER PILOTS and miners have in common? They are learning to recognize hazards using the "degraded" technique developed by the U.S. military. Traditionally, fighter pilots learned to recognize targets by studying photos taken under the best of conditions (a "highlighted" training approach). However, research showed that the pilots did better when trained with less than ideal ("degraded") pictures of the targets. "Degraded" refers to pictures where cloud cover, rain, poor weather conditions, natural barriers, buildings, or other obstructions partially hide the object—conditions that pilots would likely encounter in real life.

This approach can also be used for mine hazard recognition training. Figure 1 is a "highlighted" photo of a miner's foot positioned within a trailing cable loop on a mine floor. This photo shows the potential dangers of tripping or being caught by a retracting cable. Figure 2 shows a "degraded" version of the scene. The cable loop hazard is obvious. However, other more subtle dangers are present, including working without safety gloves and glasses.

Figure 1.—"Highlighted" scene.

Figure 2.—"Degraded" scene.

(Photos by John J. Haggerty, NIOSH Pittsburgh Research Center)

Other examples include working in a confined area between rib and equipment, and placing tools on machinery (especially if the machinery is powered up or moving). One advantage of the degraded approach is that it encourages group discussions about workplace hazards.

NIOSH researchers have found that the "degraded" technique developed by the U.S. military may be more effective than traditional methods to train miners to recognize hazards.

To compare the effectiveness of "highlighted" versus "degraded" hazard recognition training, we developed experimental and control training modules. These modules were used alternately during Part 48 training and followed with the same individual test of hazard recognition. Miners trained with the "degraded" training module scored significantly higher on the test than those trained in the more traditional "highlighted" manner. We conducted two further field studies in underground coal mines in the South and Midwest involving more than 2,600 miners. Both sites experienced more than a 25% drop in incident rates, which management and researchers attributed in part to the "degraded" hazard recognition program. However, in field studies such as this, one cannot rule out the possibility that factors other than the change of training method contributed to this reduction.

We are currently working with the Illinois Department of Natural Resources and Illinois Eastern Community College to develop a "degraded" hazard recognition training package for the mining industry. The package, including a video, slides, overheads, and an instructor's manual, will be available from MSHA's National Mine Health and Safety Academy, Beckley, WV, (304-256-3257) by fall of 1997.

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Products

Circuit Breaker Reset Devices

AN ELECTRICAL CIRCUIT breaker trips on a continuous mining machine while mining a deep cut. The circuit breaker is out under unsupported roof. Do your workers always construct temporary roof supports to safely reset the breaker? Or are they tempted to disregard safety regulations (and common sense) and go under unsupported roof to reset it? NIOSH researchers have developed plans for both manual and electrohydraulic reset systems that offer safe, practical alternatives.

Manual Reset System: The manual reset system is a simple device that allows a worker to perform the reset from beneath pinned roof by pulling on handles. The handles are attached to cables that lead to the reset lever. These cables are protected by flexible conduit and are guided by pulleys. The manual reset assemblies must be customized for each application, which is easy to do. Figure 1 illustrates one way in which the system could be installed on a continuous miner.

Electrohydraulic Reset System: The electrohydraulic system is more elaborate, but easier to use. It might best be incorporated into new machines by continuous miner manufacturers. However, it can be applied to machines in the field, especially during a rebuild. A radio remote-control system controls the reset by activating a hydraulic solenoid valve. Ideally, two spare channels on the operator's normal radio control unit would be used. Otherwise, a small radio remote-control system could be dedicated to the reset function. The hydraulic-mechanical portion of the system (figure 2) consists of a few inexpensive components. A small, double-acting hydraulic cylinder is mechanically linked to the circuit-breaker lever and is powered by a small accumulator that is charged by the continuous miner's hydraulic system during normal operation. However, the system is designed so that the lever can still be operated manually.

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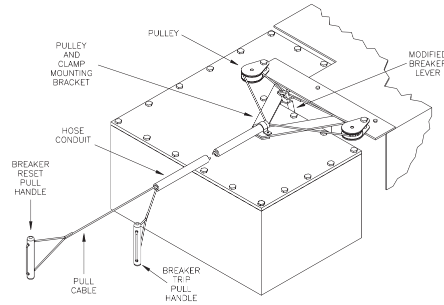

Figure 1.—Manual reset device.

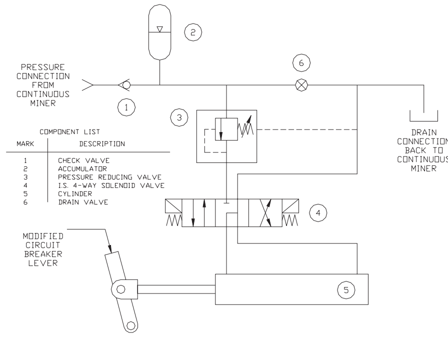

Figure 2.—Electrohydraulic reset device.

Recent Human Factors and Other Selected Mining Health and Safety Publications

1. Barrett EA, Fotta B, Rethi LL [1996]. Independent contractor trends in the United States mining industry. In: Proceedings of Minesafe International. Perth, Western Australia, Australia: pp. 357-362.

2. Bockosh GR, Peters RH [1996]. Human factors considerations in another hazardous industry: mining. In: Proceedings of the International Workshop on Human Factors in Offshore Operations, New Orleans, LA.

3. Conti RS [1994]. Fire-fighting resources and fire preparedness for underground coal mines. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 9410.

4. Cornelius KM, Turin FC [1996]. Reducing roof bolter operator cumulative trauma exposure. Holmes Safety Association Bulletin *Jan*:1-8.

5. Fotta B, Rethi LL [1996]. Independent contractor employment and accident trends in metal/nonmetal mining. Holmes Safety Association Bulletin *July*:1-4.

6. Gallagher S, Hamrick CA [1996]. Trunk extension and flexion in standing and kneeling postures: peak torque and associated electromyography of ten trunk muscles. In: Rastegar S, ed. Advances in Bioengineering. New York, NY: American Society of Mechanical Engineers, pp. 5-6.

7. Glowacki AF, Brnich MJ Jr., Mallett LG, Unger RL, Vaught C [1996]. Mine emergency response interactive training simulation. In: Proceedings of Minesim '96, the First International Symposium Via the Internet. University of Idaho, National Technical University of Athens, Greece.

8. Kyriazi N [1996]. Performance comparison of second-generation oxygen self-rescuers. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9621.

9. Mallett L, Vaught C, Brnich MJ Jr. [1996]. Emergency response veterans share the lessons they've learned. Holmes Safety Association Bulletin *Oct*:5-8.

10. Peters RH, Bockosh GR, Fotta B [1997]. Overview of U.S. research on three approaches to ensuring that coal miners work safely: management, workplace design, and training. In: Proceedings of the Japan Technical Cooperation Center for Coal Resources Development, Tokyo, Japan.

11. Pomroy WH, Carigiet AM [1995]. Analysis of underground coal mine fire incidents in the United States from 1978 through 1992. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 9426.

12. Randolph RF, Boldt CMK [1997]. Safety analysis of surface haulage accidents—Part 1. Holmes Safety Association Bulletin *May-June*:1-7.

13. Rethi LL, Fotta B [1996]. Independent contractor accident trends in the coal mining industry. Holmes Safety Association Bulletin *Aug*:1-4.

14. Unger RL [1997]. A PC-based visibility analysis software package for underground mining equipment. In: Dhar BB, Bhowmick, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., pp. 983-993.

15. Vaught C, Fotta B, Wiehagen WJ, Conti RS, Fowkes RS [1996]. A profile of workers' experiences and preparedness in responding to underground mine fires. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9584.

Free copies of the above publications may be obtained by contacting Millie Miller, (412) 892-4321 (zha9@cdc.gov). Please order by specifying publication number (1 through 15).

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Upcoming Human Factors Presentations

September 22-26, 1997 • 41st Annual Meeting of the Human Factors and Ergonomics Society, Albuquerque, NM (registration: (310) 394-1811, http://hfes.org). *An Analysis of Sprain/Strain and Repetitive Trauma Injuries in the Coal Mining Industry From 1986-1995 (poster) (S. Gallagher, D. Landen, B. Fotta).*

October 14-17, 1997 • National Mine Instructors' Conference, Beckley, WV (registration: Jimmy Shumate, MSHA, (304) 256-3353). *Successful Application of Ergonomics in Mining (S. Gallagher), Using a Mockup To Teach Emergency Communication Skills (M. Brnich, A. Cook, L. Mallett, M. Nelson, C. Vaught), Surveillance of Health and Safety in the Mining Industry (D. Landen), Human Factors Design Recommendations for Underground Mobile Mining Equipment (R. Unger, K. Cornelius), The Degraded Method: An Effective Approach to Hazard Recognition Training (K. Kowalski), A Computer-Based Mine Emergency Response Interactive Training Simulation (R. Unger, A. Glowacki), Training Simulation: Investigation of a Slip and Fall Accident (W. Wiehagen, R. Calhoun), Innovations in Mine Rescue Training (R. Conti).*

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